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A Seminar Report

on

Edge Computing

Submitted in partial fulfillment of the requirements for the final year degree in
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by

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CERTIFICATE

Certified that the Seminar topic on **Edge Computing** has been successfully presented at **RNS Institute of Technology** by **Nitish K**, bearing USN **1RN19CS092** , in partial fulfillment of the requirements for the VIII Semester degree of **Bachelor of Engineering in Computer Science and Engineering** of Visvesvaraya Technological University, Belagavi during academic year 2022-23. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the report deposited in the departmental library. The Seminar report has been approved as it satisfies the academic requirements in respect of Seminar work for the said degree.

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Acknowledgement

At the very onset, I would like to place on record our gratefulness to all those people who have helped us in making this Technical seminar work a reality. Our Institution has played a paramount role in guiding us in the right direction. I would like to profoundly thank the **Management of RNS Institute of Technology** for providing such a healthy environment for the successful completion of this seminar work.

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Abstract

Edge computing is a distributed computing model that is gaining popularity due to its ability to reduce latency, increase bandwidth, and provide better privacy and security for data processing and storage. It brings computation and data storage closer to the location where it is needed, which can be a device, a sensor, or a user. By moving computing capacity to the network's edge, edge computing reduces the processing and transmission strain on cloud computing centers while simultaneously reducing the time it takes for users to provide input.As a result, access latency could become a bottleneck and the benefits of edge computing, particularly for data-intensive services, could be overshadowed.

With Digital Transformation and emerging technologies require the massive deployment of Internet of Things (IoT) sensors while edge computing will drive the implementations. The proliferation of Internet of Things (IoT) and the success of rich cloud services have pushed the horizon of a new computing paradigm, edge computing, which calls for processing the data at the edge of the network. Edge computing has the potential to address the concerns of response time requirement, battery life constraint, bandwidth cost saving, as well as data safety and privacy.

In this paper we conduct a comprehensive survey of Edge Computing and how Edge device placement makes better performance in IoT networks and we have made a comparative study of different Edge Computing Implementation.This paper aims to inspire new edge-based IoT security designs and allow the dynamic placement of edge devices by providing a complete review of IoT security solutions at the edge layer. Finally, we present several challenges and opportunities in the field of edge computing, and hope this paper will gain attention from the community and inspire more research in this direction.

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Chapter 1

INTRODUCTION

Cloud computing has tremendously changed the way we live, work, and study since its inception around 2005. For example, software as a service (SaaS) instances, such as Google Apps, Twitter, Facebook, and Flickr, have been widely used in our daily life. Moreover, scalable infrastructures as well as processing engines developed to support cloud service are also significantly influencing the way of running business, for instance, Google File System, MapReduce, Apache Hadoop, Apache Spark, and so on. Internet of Things (IoT) was first introduced to the community in 1999 for supply chain management, and was widely adapted to other fields such as healthcare, home, environment, and transports. Now with IoT, we will arrive in the post-cloud era, where there will be a large quality of data generated by things that are immersed in our daily life, and a lot of applications will also be deployed at the edge to consume these data.

By 2019, data produced by people, machines, and things will reach 500 zettabytes, as estimated by Cisco Global Cloud Index, however, the global data center IP traffic will only reach 10.4 zettabytes by that time. By 2019, 45% of IoT-created data will be stored, processed, analyzed, and acted upon close to, or at the edge of, the network. There will be 50 billion things connected to the Internet by 2020, as predicted by Cisco Internet Business Solutions Group.Some IoT applications might require very short response time, some might involve private data, and some might produce a large quantity of data which could be a heavy load for networks. Cloud computing is not efficient enough to support these applications. With the push from cloud services and pull from IoT, we envision that the edge of the network is changing from data consumer to data producer as well as data consumer. In this paper, we attempt to contribute the concept of edge computing. We start from the analysis of why we need edge computing, then we give our definition and vision of edge computing.

Edge computing is a groundbreaking paradigm in the field of computing that has gained significant attention and traction in recent years. Edge computing has emerged as a powerful solution to address these issues by bringing computation and data storage closer to the edge of the network, closer to where data is generated and consumed. At its core, edge computing aims to decentralize data processing and computation, shifting it away from the centralized data centers that define the traditional cloud computing model. Instead, edge computing distributes these capabilities to the network's periphery, closer to the source of data generation, such as IoT devices, sensors, and mobile devices. This strategic positioning of computational resources minimizes the time it takes for data to travel back and forth from the cloud to the edge, effectively reducing latency and enabling real-time or near real-time data processing. One of the key driving forces behind the rise of edge computing is the explosive growth of the Internet of Things (IoT). IoT devices, embedded with sensors and connectivity features, generate massive volumes of data continuously. These devices often require low latency and prompt responses, making it impractical to rely solely on cloud-based infrastructures. Edge computing provides a decentralized approach that enables data to be processed locally on these devices or in nearby edge servers, ensuring quicker decision-making and enhancing overall system performance. Moreover, edge computing enhances data privacy and security. With sensitive information being processed and stored closer to the edge, there is a reduced need to transmit sensitive data over long distances or expose it to potential vulnerabilities in the cloud. This localized approach inherently reduces the attack surface and strengthens overall data protection. Additionally, edge computing enables data to be preprocessed and filtered at the edge, allowing organizations to aggregate and anonymize data before sending it to the cloud, further safeguarding privacy. Furthermore, edge computing opens up new possibilities for real-time analytics and insights. By leveraging edge resources, organizations can gain immediate insights from vast amounts of data without incurring the delays associated with data transfer to the cloud.

Chapter 2

LITERATURE SURVEY

- Title: Edge computing: Architecture, Applications and Future Perspectives.pdf

  Author: Marieh Talebkhah; Aduwati Sali; Mohen Marjani; Meisam Gordan; Shaiful Jahari Hashim ;

  The fast advancements in the fields of mobile internet and the internet of things (IoT) have caused several serious challenges for the traditional centralized cloud computing like large latency, small spectral efficiency (SE), and incompatible machine type of communication. The present article offers an overview on three edge computing technologies: mobile edge computing, cloudlets, and fog computing. Specifically, standardizing procedures, principle, architecture, and utility of the mentioned technologies will be addressed. In terms of radio access network, the mobile edge computing difference from the fog computing was described. Features of fog computing radio access networks will be addressed as well. In the end, unsolved issues and future research topics were discussed. Non-stop growth of interconnected IoT devices combined with strict requirements of IoT applications has greatly challenged the available cloud computing architectures in terms of network congestion and data privacy. One of the solutions to overcome the mentioned issues could be the migration of some computational resources near the users. Such approaches can enhance cloud efficiency by expanding its computational capability. The mentioned approach has been further developed through the introduction of several paradigms with their insights and a similar objective: higher resources deployment at the network edge. Despite their common visions, some of these paradigms are under the influence of their cases of application. For instance, the MEC paradigm allows constrained devices such as smartphones to offload some of their applications for saving resources. Mobile edge computing (MEC) focuses on bringing computational capabilities closer to the mobile network edge, typically at base stations or access points. By deploying computing resources in proximity to mobile users, MEC reduces latency and improves spectral efficiency. It enables the offloading of computation-intensive tasks from mobile devices to the edge, enhancing the overall performance and energy efficiency of mobile applications. MEC also facilitates the efficient processing of real-time data generated by IoT devices, allowing for faster decision-making and enabling new use cases such as augmented reality, smart cities, and autonomous vehicles. Fog and edge computing have gained the highest in today's research trend.[DOI: 10.1109/IICAIET49801.2020.9257824]

Advantage

The article provides an overview of three edge computing technologies and their potential solutions to challenges faced by traditional cloud computing in terms of network congestion and data privacy.

Disadvantage

The article may not offer a comprehensive or in-depth analysis of the limitations or drawbacks of edge computing technologies, and may not address potential issues with implementation or adoption.

- Title: Edge Computing: Classification, Applications, and Challenges.pdf

  Author: Gagandeep Kaur; Ranbir Singh Batth

  This paper systematically introduces the edge computing model from the aspects of basic concepts, architecture, key technologies, security and privacy protection. Edge computing provides data storage and computing at the edge of the network, and provides Internet intelligent services nearby, providing support for the digital transformation of various industries, and meeting the requirements of different industries for data diversication. Edge computing has become a hot research issue. In the future, with the continuous development of the Internet and human society, edge computing will play a more important role and effectively promote the development of various industries. It plays an important application role in Content Delivery

Network(CDN), industrial Internet, energy, smart home, smart transportation, games and other fields. Looking ahead, as the Internet and human society continue to evolve, edge computing is expected to play an increasingly significant role in driving industry development. By leveraging edge computing, these industries can enhance performance, reduce latency, improve efficiency, and deliver personalized experiences to end-users. It is poised to effectively address the unique demands of various sectors and foster innovation. With its versatility and potential, edge computing is positioned to be a crucial enabler of future advancements and transformations across multiple sectors. [DOI: 10.1109/ICIEM51511.2021.9445331]

Advantage

The paper provides a systematic introduction to the edge computing model and its various aspects, serving as a useful resource for researchers and practitioners in the field.

Disadvantage

The paper may not offer in-depth analysis or critical evaluation of the edge computing model and its limitations.

- Title:Integration of edge computing with cloud computing.pdf

  Author:Saksham Mittal; Neelam Negi; Rahul Chauhan

  A survey of virtual machine (VM) management in edge computing" provides an overview on the industrial and research projects on VM management in edge computing. The paper focuses on the virtualization frameworks and virtualization techniques, serverless management, and security advantages and issues that virtualization brings to edge computing. A survey on edge computing systems and tools" reviews existing systems and open-source projects for edge computing by categorizing them according to their design demands and innovations. In addition, topics that are related to energy efficiency and deep learning optimization of edge computing systems are discussed. Edge computing brings together IoT, big data, and mobile computing into an integrated and ubiquitous computing platform. The capability offered to deliver on-demand computing power at the edge and the ability to process the vast amount of data coming from an abundance of devices/sensors provide a huge impetus to artificial intelligence (AI) technologies.[DOI: 10.1109/ICETCCT.2017.8280340]

Advantage

The papers mentioned provide an overview of the state-of-the-art research and industrial projects on virtual machine management and edge computing systems and tools, which can be useful for researchers and practitioners in the field.

Disadvantage

The paragraph is quite general and does not provide specific details on the strengths and limitations of the surveyed virtualization frameworks, techniques, and tools.

- Title: Edge Computing.pdf

  Author:Mahadev Satyanarayanan

  In this paper, we try to integrate edge computing with the cloud computing paradigm. There are several issues and challenges in cloud computing paradigm which can be resolved by edge computing. So, in this paper we have discussed about those issues and given an idea that how edge computing is able to resolve that issues. In this paper, first we have discussed about edge computing with its definition and data flow diagram followed by its applications in various fields like smart city, smart home, cloud offloading and image and video analysis, then at last we have discussed about the issues and challenges of cloud computing followed by the idea of how edge computing can solve that issues.[DOI:10.1109/MC.2017.3641639]

  Advantage

  By integrating edge computing with cloud computing, organizations can benefit from improved data processing speed and reduced network latency. Edge computing can also enhance data security and privacy by processing data locally.

  Disadvantage

  Integrating edge computing with cloud computing can lead to increased complexity and management challenges, as well as higher costs due to the need for additional infrastructure and resources.

- Title:An Overview on Edge Computing Research.pdf

  Author:Keyan Cao; Yefan Liu; Gongjie Meng; Qimeng Sun

Edge computing is a relatively recent phenomenon in the computing world, which takes cloud computing services closer to the end user and is distinguished by fast processing and application response time, which leads to many advantages such as faster and more efficient data processing; Safety; reduced leakage on existing networks. Moreover, delaysensitive applications may benefit from the Edge computing paradigm's low latency, agility, and location awareness. Significant research has been conducted in the field of Edge computing, which is reviewed in terms of recent technologies such as Mobile Edge Computing, Cloudlet, and Fog computing, allowing researchers to gain a better understanding of current and potential solutions. This article summarizes the edge computing paradigm classification, applications, and various challenges in detail.In this paper, we came up with most of the applications require prompt response, so edge computing process the data at the edge of the network that eliminates the roundtrip travel time provides a real-time response and native authority. At last, we put forward the edge computing challenges. In the future, with the persistent advancement of the Internet and human culture, edge processing will assume a more significant job in various applications like smart homes, smart widgets, intelligent transport, quick audio, and video streaming.[DOI: 10.1109/ACCESS.2020.2991734]

Advantage

Edge computing offers faster and more efficient data processing, low latency, agility, and location awareness, which can be beneficial for delay-sensitive applications.

Disadvantage:

The challenges of edge computing need to be addressed, such as security concerns, resource constraints, and the need for standardized protocols and architectures.

Chapter 3

EDGE COMPUTING

3.1 What Is Edge Computing?

Edge computing is a "mesh network of micro data centers that process or store critical data locally and push all received data to a central data center or cloud storage repository, in a footprint of less than 100 square feet," according to research firm IDC.

Edge computing is a method of optimizing cloud computing systems by performing data processing at the edge of the network, near the source of the data. This reduces the communications bandwidth needed between sensors and the central datacenter by performing analytics and knowledge generation at or near the source of the data. This approach requires leveraging resources that may not be continuously connected to a network such as laptops, smartphones, tablets and sensors.

Edge computing covers a wide range of technologies including wireless sensor networks, mobile data acquisition, mobile signature analysis, cooperative distributed peer-to-peer ad hoc networking and processing also classifiable as local cloud/fog computing and grid/mesh computing, dew computing, mobile edge computing, cloudlet, distributed data storage and retrieval, autonomic self-healing networks, remote cloud services, augmented reality, and more. It is typically referred to in IoT use cases, where edge devices would collect data – sometimes massive amounts of it – and send it all to a data center or cloud for processing. Edge computing triages the data locally so some of it is processed locally, reducing the backhaul traffic to the central repository.

In Industrial Internet of Things (IIoT), applications such as power production, smart traffic lights, or manufacturing, the edge devices capture streaming data that can be used to prevent a part from failing, reroute traffic, optimize production, and prevent product defects. In the context of IIoT, 'edge' refers to the computing infrastructure that exists close to the sources of data, for example, industrial machines (e.g. wind turbine, magnetic resonance (MR) scanner, undersea blowout preventers), industrial controllers such as SCADA systems, and time series databases aggregating data from a variety of equipment and sensors. These devices typically reside away from the centralize computing available in the cloud. The role of edge computing to date has mostly been used to ingest, store, filter, and send data to cloud systems

3.2 Edge computing terms

- **Edge:** What the edge is depends on the use case. In a telecommunications field, perhaps the edge is a cell phone or maybe it's a cell tower. In an automotive scenario, the edge of the network could be a car. In manufacturing, it could be a machine on a shop floor; in enterprise IT, the edge could be a laptop.
- **Edge server:** Edge servers can be defined as "a computer for running middleware or applications that sits close to the edge of the network, where the digital world meets the real world. Edge servers are put in warehouses, distribution centers and factories, as opposed to corporate headquarters."
- **Edge devices:** These can be any device that produces data. These could be sensors, industrial machines or other devices that produce or collect data.
- **Mobile edge computing:** This refers to the buildout of edge computing systems in telecommunications systems, particularly 5G scenarios. Mobile edge computing is a network architecture concept that enables cloud computing capabilities and an IT service environment at the edge of the cellular network. The basic idea behind MEC is that by running applications and performing related processing tasks closer to the cellular customer, network congestion is reduced and applications perform better.

- **Edge gateway:** A gateway is the buffer between where edge computing processing is done and the broader fog network. The gateway is the window into the larger environment beyond the edge of the network.
- **Fat client:** Software that can do some data processing in edge devices. This is opposed to a thin client, which would merely transfer data.

3.3 Examples of edge devices

An edge device can be defined in several ways. You could think of it as an entry point into enterprise or service provider core networks. Examples include routers, switches, integrated access devices (IADs), multiplexers, and a variety of metropolitan area network (MAN) and wide area network (WAN) access devices. These devices also provide connections into carrier and service provider networks. Edge computing uses a range of existing and new equipment. Many devices, sensors and machines can be outfitted to work in an edge computing environment by simply making them Internet-accessible. Cisco and other hardware vendors have a line of ruggedized network equipment that has hardened exteriors meant to be used in field environments. A range of computer servers, converged systems and even storage-based hardware systems like Amazon Web Service's Snowball can be used in edge computing deployments.

In addition to specialized networking equipment, a variety of computer servers, converged systems, and storage-based hardware systems can be leveraged in edge computing deployments. For instance, Amazon Web Service's Snowball is a storage device designed for edge computing scenarios, enabling data transfer and processing at the edge. These hardware systems, combined with appropriate software and infrastructure, contribute to the distributed computing capabilities of edge computing, bringing computation and storage closer to the data source and enabling real-time or near-real-time processing.

Chapter 4

How Edge Computing works

Edge computing pushes applications, data and computing power (services) away from centralized points to the logical extremes of a network. Edge computing replicates fragments of information across distributed networks of web servers, which may spread over a vast area. As a technological paradigm, edge computing is also referred to as mesh computing, peer-to-peer computing, autonomic (self-healing) computing, grid computing, and by other names implying non-centralized, nodeless availability. To ensure acceptable performance of widely dispersed distributed services, large organizations typically implement edge computing by deploying Web server farms with clustering. Previously available only to very large corporate and government organizations, edge computing has utilized technology advances and cost reductions for large-scale implementations have made the technology available to small and medium-sized businesses. The target end-user is any Internet client making use of commercial Internet application services. Edge computing imposes certain limitations on the choices of technology platforms, applications or services, all of which need to be specifically developed or configured for edge computing. Figure 4.1 shows the architecture of edge computing.
Figure 4.2 shows the actual working of edge computing

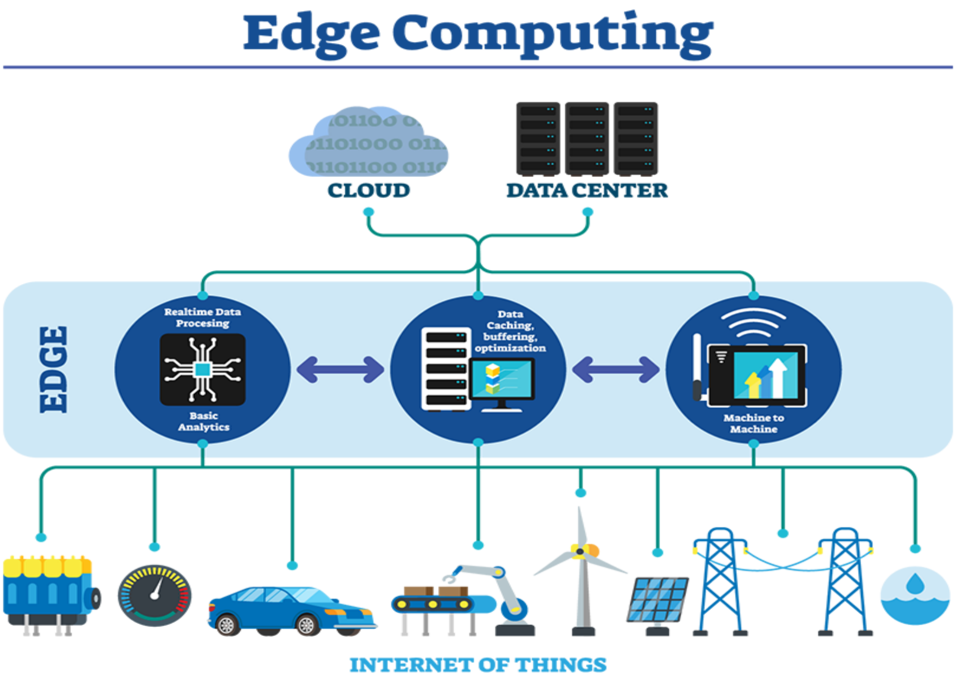

Figure 4.1: Architecture of System

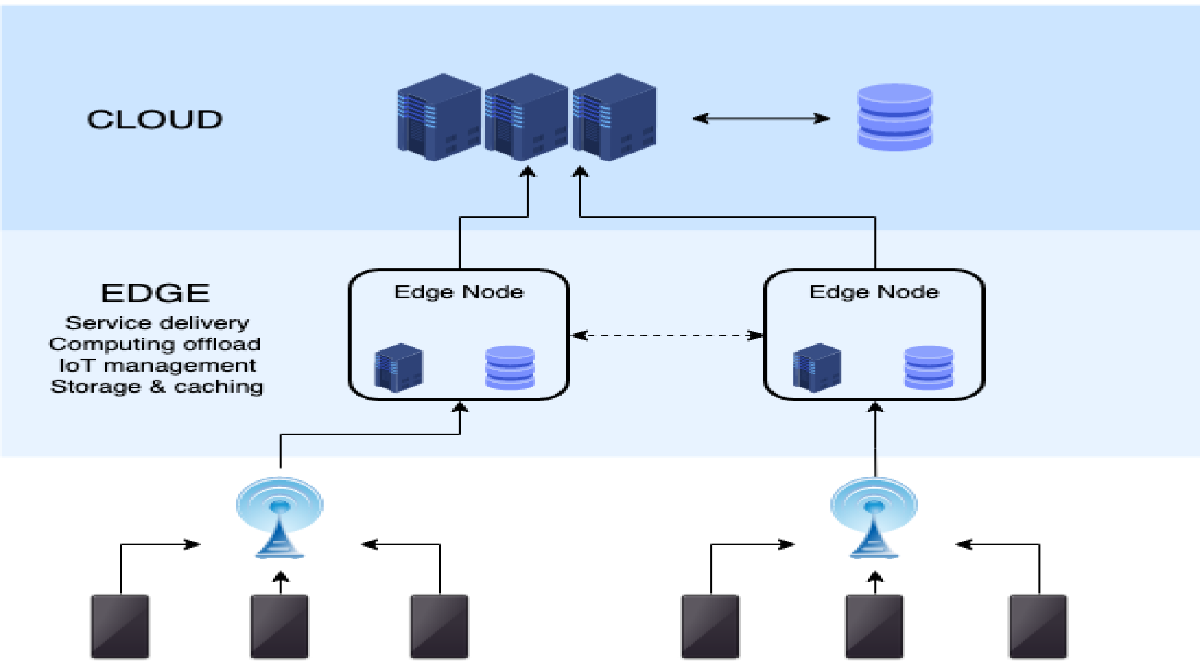

Figure 4.2: Working of System

Chapter 5

Edge Computing Methodology

5.1 Methodology used in In-hospital patient monitoring

Edge computing has emerged as a promising technology in the healthcare industry, particularly in the area of in-hospital patient monitoring. In-hospital patient monitoring involves the continuous measurement and analysis of patient vital signs such as heart rate, blood pressure, respiratory rate, and temperature. This data is critical for diagnosing and treating patients and for ensuring their safety while in the hospital.

Traditionally, in-hospital patient monitoring systems have been centralized, with data being sent to a central server for processing and analysis. However, this approach has some limitations, such as the potential for data loss due to network latency, security concerns, and the need for high-bandwidth connections.

Edge computing offers a distributed computing architecture that enables processing and analysis of data closer to the source, i.e., at the edge of the network, which can address these limitations. In an edge computing-enabled in-hospital patient monitoring system, the data is processed and analyzed locally at the edge devices such as sensors, wearables, and gateways. This reduces the amount of data that needs to be transmitted to the central server, reducing network latency, and improving the reliability and security of the system.

Edge computing also enables real-time monitoring of patient vital signs and can trigger alerts in case of any abnormalities, allowing for timely intervention by healthcare professionals. This is particularly important in critical care settings where delays in response can have serious consequences for the patient's health.

Another advantage of edge computing in in-hospital patient monitoring is its ability to enable personalized patient care. Edge devices can collect data on a patient's vital signs, activity level, and other health-related metrics and use this data to generate personalized insights that can inform the patient's care plan.

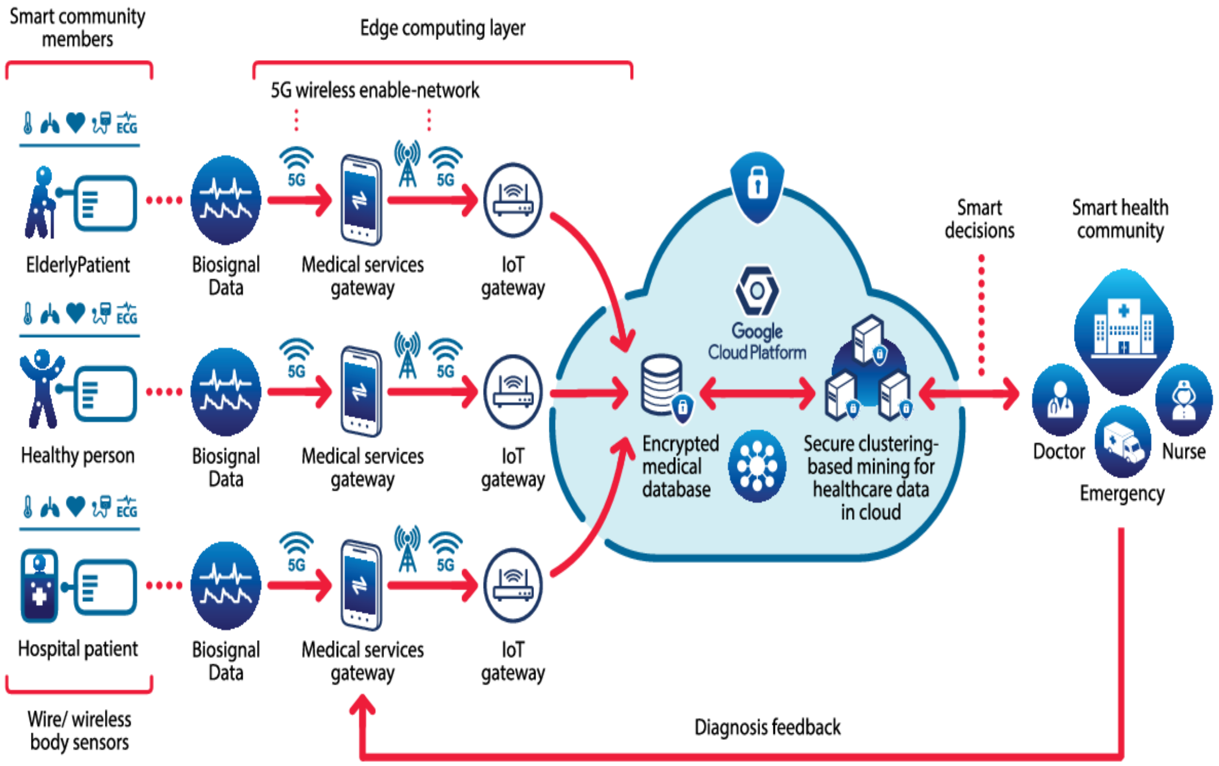

Figure 5.1: In hospital patient monitoring

Furthermore, edge computing can also help reduce healthcare costs by enabling remote monitoring of patients. Patients can be monitored from their homes, reducing the need for hospital readmissions and allowing healthcare professionals to intervene proactively if any issues arise.

Healthcare now contains several edge opportunities. Currently, monitoring devices (e.g. glucose monitors, health tools and other sensors) are either not connected, or where they are, large amounts of unprocessed data from devices would need to be stored on a 3rd party cloud. This presents security concerns for healthcare providers.

An edge on the hospital site could process data locally to maintain data privacy. Edge also enables right-time notifications to practitioners of unusual patient trends or behaviours (through analytics/AI), and creation of 360-degree view patient dashboards for full visibility.

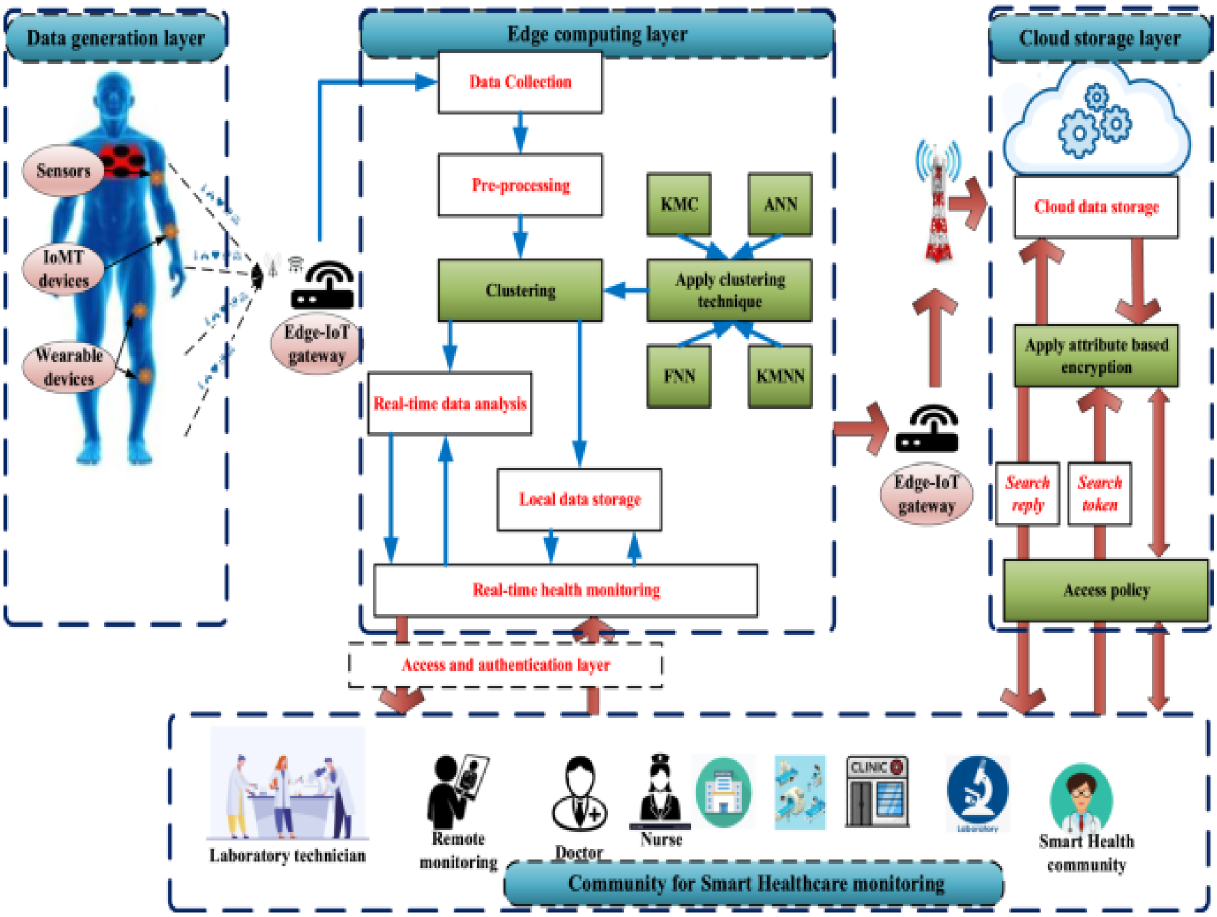

Figure 5.2: In hospital patient monitoring

Wearables can give clinicians a timely status of key patient vitals such as heart rate and blood pressure, alerting medical staff to issues before they become problems. Health monitors can aid remote care by collecting patient data and triggering actions based on the results—for example, monitoring blood glucose levels and sending that information to a companion device such as an insulin pump to dispense the insulin. AI-powered imaging models can detect potential concerns in X-rays, prioritizing those images for radiologist or physician review.

The potential of these emerging innovations is profound, leading to better clinician workflows, lower costs, and improved patient care. But these edge devices have something else in common: they all generate data. As a result, healthcare systems and providers must decide how to manage and make the best use of these unprecedented volumes of data.

Moreover, edge computing in hospitals can enhance data privacy and security. Instead of transmitting sensitive patient data to external cloud servers, edge computing enables local storage and processing of data, minimizing the risk of unauthorized access or data breaches. This approach aligns with stringent healthcare data protection regulations and provides an additional layer of security for sensitive medical information.

The HealthFog framework based on Edge Computing devices with deep learning . It can automatically analyze heart disease to provide lightweight fog or healthcare services and efficiently manage heart patients' data from IoT devices. In blockchain and ABE techniques have been used to protect medical data. The CPABE technique has been used in to maintain the secure monitoring of healthcare data. In, IoT, cloud and edge-based healthcare systems with blockchain have been proposed to provide data security during monitoring. Homomorphic encryption based on mutual privacy-preserving using the K-means strategy ensures the protection between participants and the cluster centre. The authors in have proposed an IoT with a cloud-based healthcare system. It uses an IP-based multimedia service called IP Multimedia Subsystem (IMS) to monitor patients' health conditions remotely. The Session Initiation Protocol (SIP) communicates with the IMS core and transmits data. This system can handle emergencies by implementing an alert system which makes calls and sends messages automatically in real-time. The sources of data are sensors, apps, and smartwatches.

In conclusion, edge computing has the potential to revolutionize in-hospital patient monitoring by enabling real-time monitoring, personalized patient care, and remote monitoring while addressing the limitations of traditional centralized systems. The adoption of edge computing in healthcare is still in its early stages, but it is expected to grow rapidly in the coming years as more healthcare organizations recognize its benefits. In the hospital scenario, edge computing can significantly improve healthcare delivery by enabling real-time data analysis, faster decision-making, predictive analytics, and enhanced data privacy and security. It empowers healthcare providers with actionable insights, facilitates timely interventions, and ultimately enhances patient care and outcomes.

Chapter 6

Edge computing applications and challenges

6.1 Applications

6.1.1 Autonomous vehicles

Autonomous platooning of truck convoys will likely be one of the first use cases for autonomous vehicles. Here, a group of truck travel close behind one another in a convoy, saving fuel costs and decreasing congestion. With edge computing, it will be possible to remove the need for drivers in all trucks except the front one, because the trucks will be able to communicate with each other with ultra-low latency.

6.1.2 Remote monitoring of assets in the oil and gas industry

Oil and gas failures can be disastrous. Their assets therefore need to be carefully monitored. However, oil and gas plants are often in remote locations. Edge computing enables real-time analytics with processing much closer to the asset, meaning there is less reliance on good quality connectivity to a centralised cloud.

6.1.3 Smart grid

Edge computing will be a core technology in more widespread adoption of smart grids and can help allow enterprises to better manage their energy consumption.

Sensors and IoT devices connected to an edge platform in factories, plants and offices are being used to monitor energy use and analyse their consumption in real-time. With real-time visibility, enterprises and energy companies can strike new deals, for example where high-powered machinery is run during off-peak times for electricity demand. This can increase the amount of green energy (like wind power) an enterprise consumes. Figure 9.1 shows smart grid

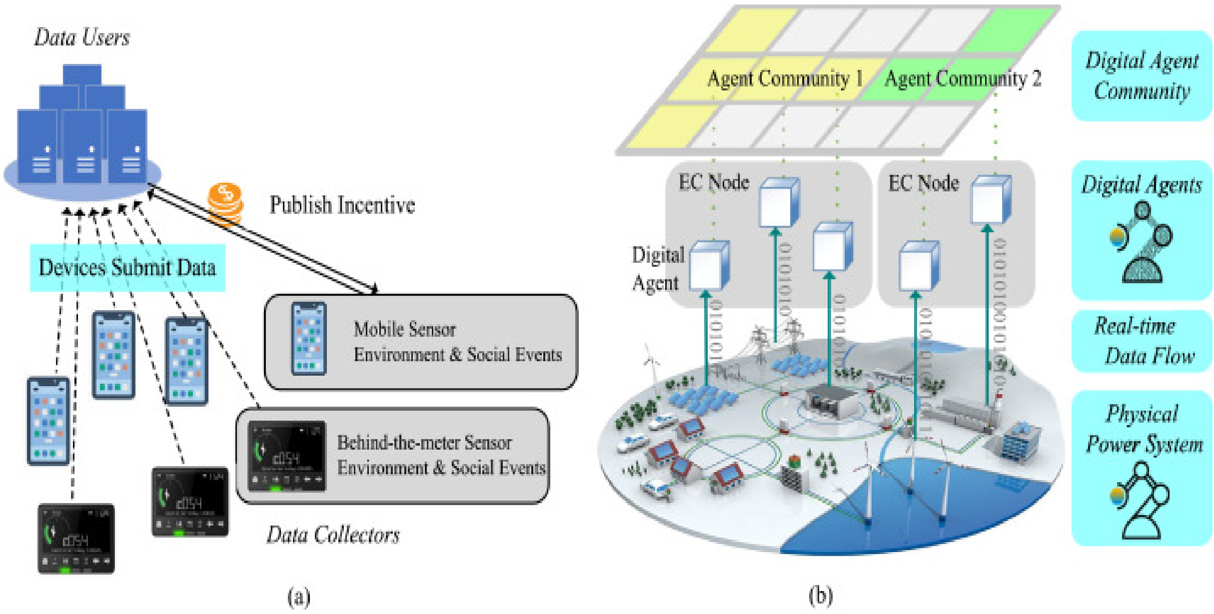

Figure 6.1: Smart grid

6.1.4 Content delivery

By caching content – e.g. music, video stream, web pages – at the edge, improvements to content deliver can be greatly improved. Latency can be reduced significantly. Content providers are looking to distribute CDNs even more widely to the edge, thus guaranteeing flexibility and customisation on the network depending on user traffic demands.

6.1.5 Traffic management

Edge computing can enable more effective city traffic management. Examples of this include optimising bus frequency given fluctuations in demand, managing the opening and closing of extra lanes, and, in future, managing autonomous car flows.With edge computing, there is no need to transport large volumes of traffic data to the centralised cloud, thus reducing the cost of bandwidth and latency.

6.1.6 Cloud gaming

Cloud gaming, a new kind of gaming which streams a live feed of the game directly to devices, (the game itself is processed and hosted in data centres) is highly dependent on latency.
Cloud gaming companies are looking to build edge servers as close to gamers as possible in order to reduce latency and provide a fully responsive and immersive gaming experience. Figure 9.1 shows cloud gaming

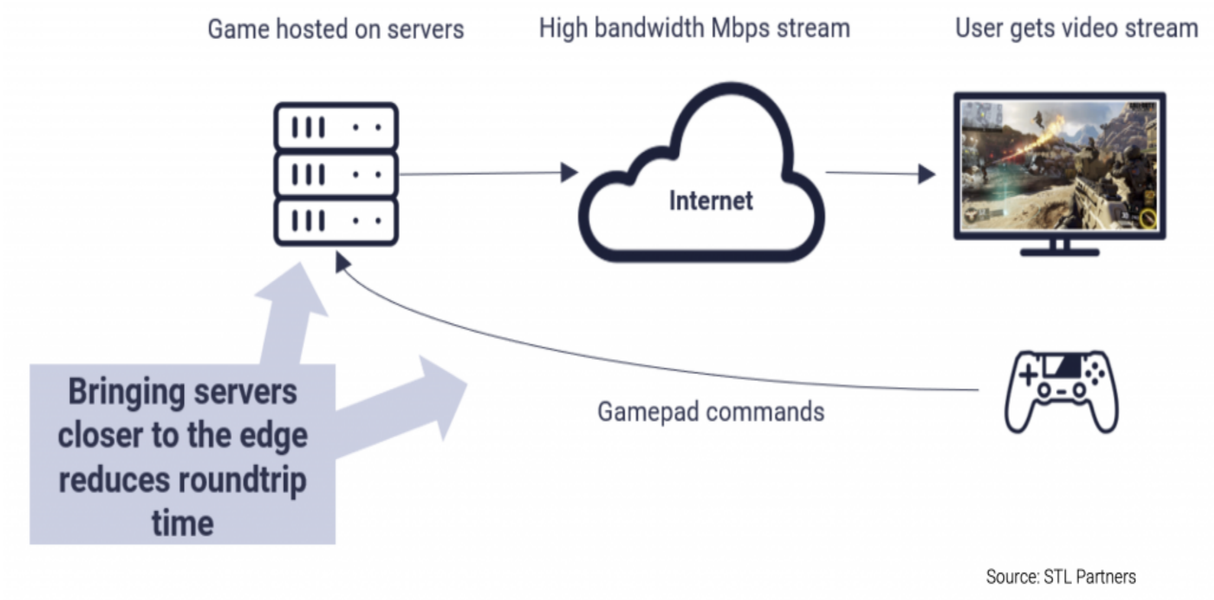

Figure 6.2: Cloud gaming

6.2 Edge computing challenges

Edge computing brings much-needed efficiency to IoT data processing. This aspect helps to maintain its timely and consistent performance. However, there are also a couple of challenging issues that come with the good stuff. Overall, five key challenges come with the implementation of edge computing applications. Let's take a closer look:

- **Network bandwidth:** the traditional resource allocation scheme provides higher bandwidth for data centers, while endpoints receive the lower end. With the implementation of edge computing, these dynamics shift drastically as edge data processing requires significant bandwidth for proper workflow. The challenge is to maintain the balance between the two while maintaining high performance.
- **Geolocation :** edge computing increases the role of the area in the data processing. To maintain proper workload and deliver consistent results, companies need to have a presence in local data centers.
- **Security:** Centralized cloud infrastructure enables unified security protocols. On the contrary, edge computing requires enforcing these protocols for remote servers, while security footprint and traffic patterns are harder to analyze.
- **Data Loss Protection and Backups:** Centralized cloud infrastructure allows the integration of a system-wide data loss protection system. The decentralized infrastructure of edge computing requires additional monitoring and management systems to handle data from the edge.
- **The edge computing framework:** Requires a different approach to data storage and access management. While centralized infrastructure allows unified rules, in the case of edge computing, you need to keep an eye on every "edge" point.

Chapter 7

CONCLUSION

7.1 CONCLUSION

The adoption of cloud computing brought data analytics to a new level. The interconnectivity of the cloud enabled a more thorough approach to capturing and analyzing data.With edge computing, things have become even more efficient. As a result, the quality of business operations has become higher.

Edge computing is a viable solution for data-driven operations that require lightning-fast results and a high level of flexibility, depending on the current state of things. The idea is to get closer to devices to reduce the amount of data that needs to be transferred, which results in better response time.As a result, the quality of business operations has become higher.

Edge computing is particularly relevant in the context of IIoT, where it enables real-time processing of data from sensors and devices, enabling faster decision-making and reducing the need for large amounts of data to be transmitted to the cloud. As the IoT and IIoT continue to grow and become more complex, edge computing will undoubtedly become even more critical in enabling efficient, real-time processing of dat

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